ECOLOGY OF ARCTIC FOXES AT PRUDHOE BAY, ALASKA

A

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ECOLOGY OF ARCTIC FOXES AT PRUDHOE BAY, ALASKA

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ABSTRACT

Ecology of arctic foxes (*Alopex lagopus*) was studied at Prudhoe Bay, Alaska, during summer 1979 to assess impacts of northern oil development. Thirty-five adults used 23 of 26 dens. At least 53 pups were whelped at 11 family dens, 26 to 35 survived until the end of August. Lemming abundance was low. Foxes utilized artificial foods, though analysis of 105 scats showed small mammal remains in 87 percent, birds in 38 percent, and garbage in 26 percent. Availability of artificial and natural foods contributed to unusually high fox densities. Diseases such as rabies may be transmitted among foxes occurring in high densities.

The first ethogram for arctic foxes is presented, identifying 11 major behavioral categories. Pups combined rapid behavioral changes with rapid physical growth. Families seemingly dissolved in three stages: increasing avoidance between adults, between adults and pups, then between pups.

Home ranges for individual pups varied from 5.4 to 17.7 km^2, and combined ranges for all pups from one family covered 37.8 km^2.

ACKNOWLEDGEMENTS

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P. Gipson invited me to make the study and assisted in all of its phases. He reviewed the manuscript and guided me in making observations of canids in the wild. E. Follmann read the manuscript and made many useful suggestions throughout the study. S. Harbo also read the manuscript. R. Burgess read the chapter on Social Behavior and enhanced it with many unique data. I benefited from conversations with D. Klein about Alaska, wildlife, and academics. P. Mickelson kindly agreed to serve on my advisory committee on short notice.

At Prudhoe Bay, Atlantic Richfield Co. and Sohio-British Petroleum Co. provided logistic support and freely granted access to their roads. J. Perry opened the excellent facilities of Construction Camp 2 to our general use. A. Hendrick was my field assistant and D. Vernam assisted with the scat analysis. H. Stockholm expertly directed the manuscript preparation.

Lastly I am grateful to my friends S. Shostak and T. Katt, who taught me about animals as well as myself.

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INTRODUCTION

Background

In January 1968, an exploratory well drilled a short distance from Prudhoe Bay struck a deposit of oil and natural gas. A second drilling rig was moved approximately 11 km to the southeast and in July 1968, drilling confirmed discovery of the largest oil field in North America: 9.6 billion barrels of recoverable high-grade crude oil.

In June 1969, an oil company consortium filed for permit with the Bureau of Land Management to construct a pipeline stretching 1288 km from Prudhoe Bay to the southern icefree port of Valdez. Litigation continued until 17 November 1973 when President Nixon signed the Trans-Alaska Pipeline Authorization Act, directing the Department of the Interior to issue necessary construction permits and declaring the pipeline project to be in the national interest.

Construction on a gravel service highway from the Yukon River to Prudhoe Bay began on 29 April 1974 and was completed in 154 days. On 27 March 1975 the first section of pipe was put into place, and the first oil flowed into the pipeline on 20 June 1977. As of July 1979, the Prudhoe Bay oil field had produced 700 million barrels of oil, with 191 wells capable of production in the field.

Starting in 1974, a large scale project was initiated by the Energy Research and Development Agency (now Department of Energy: DOE) to monitor the impact of oil development on the habitat and wildlife of northern Alaska. In 1979 support for the project was provided through

Battelle Pacific Northwest Laboratory. (Other pipeline impact research was summarized by Klein [1979]).

In addition to arctic fox (*Alopex lagopus*) biology the DOE program has examined small mammal populations, nesting success of birds, lichen communities, caribou (*Rangifer tarandus*) range quality, Eskimo Cesium-137 uptake, and other issues, designed to provide a unified description of an environment undergoing major changes (*see* Hanson and Eberhardt 1979).

Research on arctic foxes has been conducted in both disturbed and undisturbed areas. Major study sites included the Prudhoe Bay oil field and the Colville River delta, an undisturbed area approximately 80 km west of Prudhoe Bay. Much of the research on arctic foxes at Prudhoe Bay focused on locating dens and describing local movements of adults and the biology of the species in general (Eberhardt 1977, Hanson and Eberhardt 1979). The main objective of the present study was to examine the life history of juvenile arctic foxes in a disturbed area, specifically to assess how the movements, behavior, and diet of pups may be affected by oil development activities. Population densities of arctic foxes and their major prey, lemmings, were also assessed.

Literature Review

The most recent comprehensive study of arctic fox biology in North America was conducted by Macpherson (1969) working in Keewatin District, Northwest Territories, Canada. Chesemore (1967) described the general biology of arctic foxes near Barrow and Teshekpuk Lake,

Alaska. Prior to the recent DOE research little data were recorded on the biology of arctic foxes in northeast Alaska. Underwood (1975) has since provided some general observations on arctic foxes at Prudhoe Bay. Eberhardt (1977) described more fully the den ecology of arctic foxes and red foxes (*Vulpes vulpes*) in northern Alaska, and Eberhardt and Hanson (1978) summarized several long distance movements made by arctic foxes tagged at Prudhoe Bay and elsewhere in northern Alaska.

Additional monographs have been prepared for arctic foxes in the U.S.S.R. (Boitzov 1937, Shibanoff 1951, Tchirkova 1953, Dementyeff 1955), and Greenland (Braestrup 1941, Vibe 1967). Considerable research has focused on forecasting pelt harvests (Tchirkova 1951, 1955, Macpherson 1969), though the overall abundance and wide distribution of arctic foxes commands considerable biological, as well as economic, interest. Arctic foxes are ideally suited to provide an index of food-based changes in the environment since their local productivity generally reflects the vigor of small mammal populations in the area (Braestrup 1941, Tchirkova 1951, Macpherson 1969, Wrigley and Hatch 1976). Such an index may be important when assessing the broad environmental impacts of oil development in northern Alaska. This study is part of a continuing effort to assess those impacts.

Species Account

Arctic foxes are among the smallest and most solitary of the canids, and they feed primarily on small mammals, particularly lemmings, though birds, fish, and carrion are also eaten. The scientific name,

Alopex lagopus, translates from Greek as "hare-footed fox," and refers to the heavily furred feet.

Arctic foxes stand approximately 28 cm at the shoulder; adult body lengths range from 45 to 68 cm and the tail provides an additional 25 to 43 cm (Walker 1968). In general size and build the fox resembles a large domestic cat. Thirty-four adult foxes weighed at Prudhoe Bay from 1975 to 1978 (L. Eberhardt unpubl. data) ranged from 2.75 to 4.55 kg (mean = 3.47 kg). One fox of unrecorded age weighed 6.7 kg and Walker (1968) noted 9 kg as maximum weight.

Arctic foxes are found throughout the arctic tundra. Nelson (1887) observed "the wilder and more sterile the country the more abundant this fox appears to be." Distribution records for arctic foxes in Alaska were summarized by Chesemore (1968a). In general the species occurs throughout the northern and western tundra regions. Movements south of tree line as have been reported for the U.S.S.R. and Canada are probably restricted in Alaska by the Brooks Mountain Range (Rausch 1950), although arctic foxes are occasionally trapped as far south as the Yukon River (D. Ritter pers. comm.).

Arctic foxes are the only canids that undergo marked seasonal color changes. There are two normal color phases, so-called "blue" and "white". In summer the white fox becomes brown over most of the face, back, and legs, and beige on the ventrum, sides, and tail. Starting in late summer, these foxes turn white. Blue foxes retain a slated appearance throughout the year.

Arctic foxes are equipped to survive one of the most severe climates on earth. Their dense winter coat consists of four overlapping layers of hairs, providing adequate insulation for survival of experimental temperatures below -60°C (E. Follmann pers. comm.). Follmann (1978) has shown that in a curled position, arctic foxes can maintain the air temperature within the curl as much as 52°C above ambient air temperature. Body extremities are reduced to minimize heat lost to the environment, and light weight and broad furred paws combine to facilitate travel over crusty snow (Wrigley and Hatch 1976).

Increased intraspecific contact as may occur around carcasses during winter, or during migrations, makes arctic foxes especially susceptible to rabies (Rausch 1973). Canids in general and foxes in particular are well known vectors of this disease. It is not known how or where the virus remains latent during a long incubation period in foxes (Kaplan and Koprowski 1980), but combined with the species' naturally high susceptibility to rabies, arctic foxes may carry the infection over long distances before succumbing. A rabid fox was found, for instance, on an ice island in the Arctic Ocean 1100 km north of the nearest land (Rausch 1973). In addition, the virus has retained its infectivity for two years in the brains of foxes frozen in experimental conditions (Rausch 1973). Thus in the arctic rabies is probably preserved and transmitted to scavengers feeding on the carcasses of infected animals. In Alaska most cases are recorded during late winter when local densities of foxes are high and contact between foxes is increased (Rausch 1973). Carcasses of foxes in their winter pelage, presumably killed by

rabies, may be commonly found in some areas, including Prudhoe Bay (Hanson and Eberhardt 1977).

THE STUDY

1. Study Area

Physiography

Prudhoe Bay lies at approximately 148°35'W longitude and 70°20'N latitude along the Beaufort Sea coast of northern Alaska. The majority of oil development facilities are spread over an irregularly shaped area extending from Prudhoe Bay approximately 20 km west to the Kuparuk River, 10 km east to the Sagavanirktok River, and 13 km south to Deadhorse airport. The oil field contains more than 200 modular buildings, including three airports, a central power plant, gathering and flow stations, gas injection and compressor stations, drilling wells, one pump station, and living quarters for approximately 3000 workers. All buildings are connected by a gravel road system. The road system and major facilities at Prudhoe Bay are shown in Figure 1.

The North Slope region of Alaska encompasses the drainage basins of all rivers flowing north from the Brooks Range, and includes three distinct physiographic units: the southern foothills, northern foothills, and Arctic Coastal Plain (A.E.I.D.C. 1975).

The Prudhoe Bay oil field is situated on the Arctic Coastal Plain. Local relief is flat and elevation is fairly constant at about 15 to 23 m above sea level. The area is treeless and underlain by continuous permafrost. Drainage is poor and after spring thaw the flat surface is inundated with shallow lakes and ponds. Pingos, tussocks, and ice-wedge polygons are common features of the landscape.

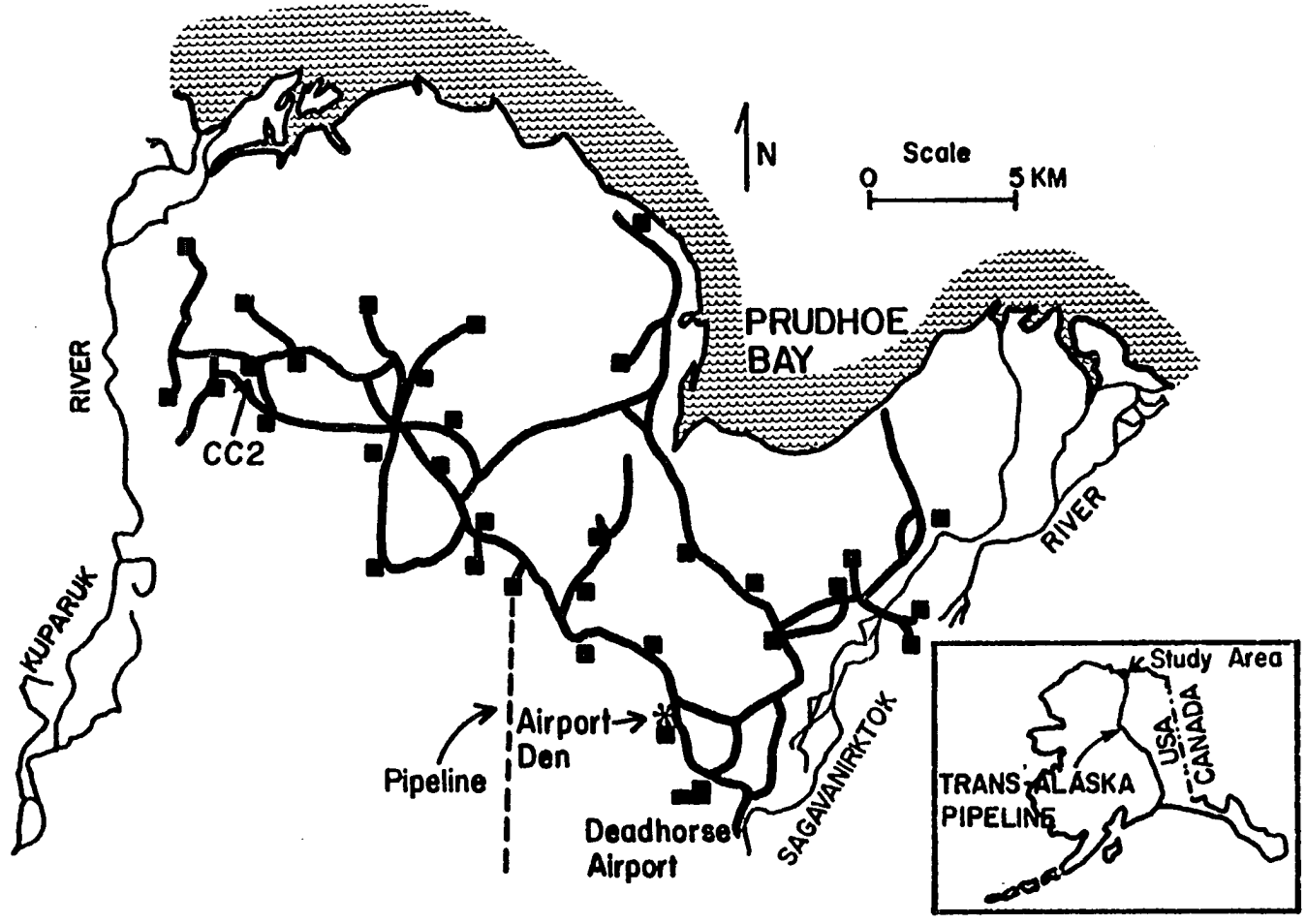

Figure 1. Major oil facilities (black squares) and connecting gravel roads at Prudhoe Bay. Main study sites included Construction Camp 2 (CC2) and Airport den.

Seasons

The Arctic Coastal Plain is characterized by a long, dark, and cold winter followed by a short summer of continuous light. The mean temperature for January, the coldest month, is between -20° and -30°C; and the mean temperature for July, the warmest month, is between 1° and 8°C (Brown *et al.* 1975).

Surface winds blow almost continually on the coast, calm conditions are recorded only one percent of the time (A.E.I.D.C. 1975). Annual precipitation is from 15 to 35 cm, the entire area is classified as desert. Most of the annual 0.75 to 1.0 m snowfall occurs during October with gradually decreasing amounts falling monthly through May.

Strong winds, normally blowing from the east, occasionally drive the ground snow into blinding "white-outs". Visibility is further restricted by fog starting when open sea water first appears generally in June. Visibility is reduced to 400 m or less on 40 percent of all summer days at Barrow, Alaska (A.E.I.D.C. 1975), and the percentage is comparable at Prudhoe Bay. Driving was hazardous and direct observations of wildlife beyond 20 m were impossible in heavy fog.

Vegetation

The Prudhoe Bay area habitat is typically classified as wet-tundra type (A.E.I.D.C. 1975). Tundra refers to the rolling, treeless plains of arctic and alpine regions throughout the world. The more specific "wet-tundra" classification is characterized by the presence of innumerable small lakes, along with a regular mosaic of raised polygon ridges.

Thirteen distinct vegetation types were described for the Prudhoe Bay area by Webber and Walker (1975). A provisional checklist to the vascular plants, lichens, and mosses of Prudhoe Bay was developed by Murray and Murray (1975). The most common flora of the Prudhoe Bay area include assorted mosses (*Sphagnum* spp.), cottongrass (*Eriophorum angustifolium*), assorted sedges (*Carex* spp.), marsh marigold (*Caltha palustris*), snow buttercup (*Ranunculus nivalis*), purple mountain flower (*Saxifraga oppositifolia*), bog rosemary (*Andromeda polifolia*), cloudberry (*Rubus chamaemorus*), lousewort (*Pedicularis parviflora*), willows (*Salix* spp.), and cranberry (*Vaccinium vitis-idaea*).

Many of the differences in vegetation are related to micro-relief surrounding polygon edges. With practice, arctic fox dens can be discerned at a distance due to typical location on raised relief and accompanying lush vegetation. This den vegetation has been described for the Bolshezemelskaya tundra, U.S.S.R. (Dementyeff 1955); Keewatin District, Canada (Macpherson 1969); Teshekpuk Lake, Alaska (Chesemore 1969); and the North Slope, including Prudhoe Bay (Eberhardt 1977).

2. Study Methods

Field work was conducted from 25 May through 24 August 1979. I was unable to study foxes in all areas of the oil field with equal intensity because of restricted access to some sections and heavy machinery traffic in other sections. However, most of the oil field was visited twice by vehicle or on foot. Nearly all observations of foxes were made from a vehicle, often as close as 10 m away.

Tagging and Radio Telemetry

Four adult and seven juvenile arctic foxes were captured in live traps and tagged in both ears and outfitted with collars containing radio transmitters. One additional pup was similarly radio-collared after it was captured by hand. Tuna fish proved a satisfactory bait. Sardines were less satisfactory since foxes were able to remove this bait without triggering the traps. Traps were normally set on active fox dens or along preferred travel routes and checked every four hours.

In all cases but one, foxes were injected with ketamine hydrochloride before tagging. This proved necessary since our first attempt showed the traps were too large to efficiently handle and remove the trapped animal. A satisfactory dosage was 0.2 cc for pups and 0.4 cc for adults. The drug was injected intramuscularly, usually in the thigh. A second, smaller injection was occasionally used when foxes began to recover before handling was completed. Foxes were pinned to the side of the cage with a stick, injected, and then removed. The drug took full effect within 5 minutes and the tagging operation was usually completed within 10 minutes. All foxes recovered fully within 30 to 60 minutes.

Each fox was marked with a rounded teflon tag in one ear and a Standard Rototag in the other ear. Both tags were serially numbered and stamped with a return address. The teflon tag was additionally marked with a $20 reward offer. Colored vinyl strips about 5 cm long were attached to each tag to further aid field identification. Transmitters operating in the 216-MHz range were encased in acrylic and

fastened to leather collars along with pliable whip antennas. Each collar weighed from 60 to 100 g depending on the size of the transmitter. Radio collars never exceeded seven percent of the body weight of pups (mean = four percent) or more than two percent of the body weight of adults (the mean is slightly less than two percent).

Transmitters had a minimum life expectancy of three months and detectable signals were obtained at ranges up to 3 km throughout the summer. The frequency for one adult male was improperly recorded and no data on his movements were collected.

Receiving equipment consisted of dual directional antennas mounted to the roof of our vehicle with leads connected to an AVM receiver unit. Radio-collared foxes were located by rotating the antennas until arriving at a signal at maximum strength. Frequently the peak signal continued over an arc of about 40° which we bisected roughly since the null-peak signal system worked erratically. Several field tests indicated a true bearing resolution within ± 5°; often ± 1-2°.

Telemetry monitoring was minimal in July since most pups remained near natal dens. We usually attempted to locate individuals who were away from natal dens twice a day; early in the morning, then again early in the evening. Telemetry monitoring became more important in August when pups spent more time at greater distances away from natal dens. Foxes were monitored at all hours of the day, although approximately three-fourths of the 150 total monitoring hours were spent monitoring pups between 0800 and 2000 hours. As we became better acquainted with individual movement patterns, it was possible to monitor and record

the locations of as many as five foxes at half-hour intervals for sessions of several hours.

Main Study Den

The family selected for intensive study established its natal den beneath the 2 m thick, 45,000 m^2 rectangular gravel pad of a large construction camp (CC2) near the western limit of the oil field (Figure 1). The den was located at the southwest corner of the pad and extended along tunnels made for buried utility lines throughout an area of approximately 3200 m^2 (Figure 2). The CC2 family included both parents and a litter of seven pups, of which we trapped two female pups, three male pups, and the adult male.

Food Habits and Behavior Monitoring

Food remains at dens were recorded during den surveys. We also attempted to identify prey items being carried by adult foxes to dens. Scats were collected at dens during den surveys, or wherever found. Since single droppings often consisted of two or more pellets, it was difficult to relate droppings to particular defecations. Also, several foxes may defecate on the same spot. Accordingly each pellet was collected separately and given equal weight in the analysis. Because of potential *Echinococcus multilocularis* infection, scats were not handled directly in the field, and were subsequently frozen and autoclaved. Scats collected in early summer were made unusable by an accident in autoclave procedure, with the result that only late summer scats, all collected at CC2 and its secondary den, were analyzed.

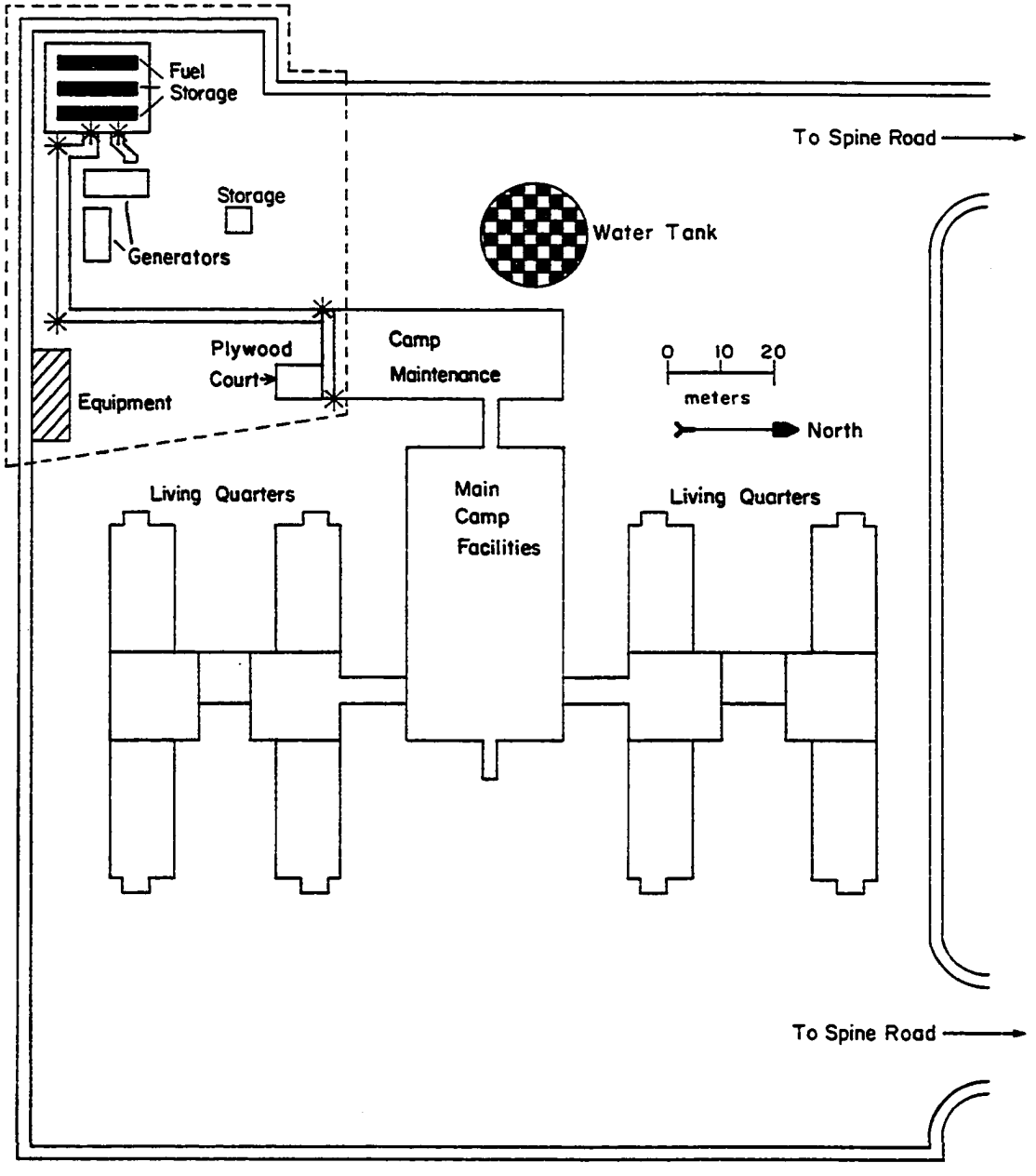

Figure 2. Ground plan of Construction Camp 2 at Prudhoe Bay. The arctic fox den area is enclosed by the dashed line. Main den entrances are indicated by asterisks, and are interconnected by underground runways.

Scats were fragmented manually and prey remains identified using reference collections at the University of Alaska. Small mammal remains consisted primarily of hair, though teeth and bones occasionally proved diagnostic. Bird remains consisted of shell fragments, feathers, and bones. We considered tin foil, styrofoam, cloth, and similar items, as well as artificial foods (where identified) as garbage.

Observations of foxes utilizing artificial foods at garbage dumps, or taking food handouts from oil field employees, were also recorded.

Behaviors of arctic foxes were recorded at quarter-hour intervals. Continuous and staggered 24 hour observation shifts were attempted, but were often disrupted by fog or heavy machinery traffic. All hours of the day were sampled, although approximately three-fourths of the 300 total hours of behavior monitoring were made between 0800 and 2000 hours.

Arctic foxes throughout the oil field were observed for approximately 400 hours. During the study 16,000 km were coursed by vehicle and on foot.

RESULTS AND DISCUSSION

1. The Arctic Fox Population at Prudhoe Bay

A survey of arctic fox dens was conducted on the resource development area extending west from Prudhoe Bay to the Kuparuk River, east to the Sagavanirktok River, and south to Deadhorse airport (Figure 1). The locations of 10 dens in this area were given by Eberhardt (1977). L. Eberhardt (pers. comm.) provided the locations for several other dens, and six additional dens were found by us. At least 26 dens occurred in approximately 390 km^2, an average of one den per 15 km^2. There were probably several other dens in the area judging from the appearance of an arctic fox family not associated with known dens in late summer, and our inability to locate two families which abandoned natal dens. In addition, at least seven additional dens are located north of the area surveyed (L. Eberhardt pers. comm.).

We visited most dens in early June then again in early August and classified them according to intensity of fox use. In June, molting fur clings to entered burrows and lies scattered about resting spots on dens. This provided precise clues to early den visitation and use by arctic foxes. Fox trails and food remains around dens indicated more intensive use. Large tailing piles (left from the cleaned birth burrow) and numerous freshly dug cache holes (mostly made by pups during play) indicated the presence of pups. Pups also left numerous scats around the den area.

The 26 dens surveyed were classified as follows: 3 (12 percent) had no sign of fox use, 5 (19 percent) showed signs of visitation by arctic foxes, 2 (8 percent) had freshly cleaned burrows, 3 (12 percent) had numerous fox tracks and food remains lying about, and 13 dens (50 percent) had pups present sometime during the summer. Pups were observed at 12 dens and a complete litter of six pups, bitten to death, was found at another den by oil field employees. The precise location of this den was not recorded. Locations of all other dens surveyed are shown in Figure 3.

Eleven families of arctic foxes were identified in the Prudhoe Bay area. This was a moderate-to-high level as compared with 12 and 17 families found in 1975 and 1976, respectively (Hanson and Eberhardt 1979).

Stephenson (1970) found a mean density of one arctic fox den per 216 km^2 on St. Lawrence Island. Macpherson (1969) reported a mean density of one den per 36 km^2 in the Aberdeen Lake area, Northwest Territories, Canada. Reported densities of arctic fox dens are generally higher in the U.S.S.R. and agree closely with the density found for Prudhoe Bay. Dementyeff (1955) found a mean density of one den per 16 km^2 in the Bolshezemelskaya tundra region, and Shibanoff (1951) working in unspecified areas of the U.S.S.R. (perhaps on Kanin Peninsula: Macpherson 1969) found one den per 14 km^2, but noted high densities of one den per 1.7 km^2 to one den per 10 km^2 may occur. Boitzov (*in* Macpherson 1969) estimated the mean density of arctic fox dens for the entire tundra region of the U.S.S.R. to be one den per 32 km^2.

The dispersion of dens at Prudhoe Bay (Figure 3) was tested for randomness (Clark and Evans 1954). The ratio (R) between calculated mean nearest neighbor distance and expected mean nearest neighbor distance equals one if den locations occur at random. If there is no spacing between dens and all occur at one spot, R equals zero. If all dens (except those at the periphery) are equidistant from each of six neighbors, R equals 2.1491 and spacing is maximal.

The spacing of family dens at Prudhoe Bay does not depart significantly from random ($p = .15$, $R = 1.21$). However, denning foxes did keep their distance from one another as was also observed by Macpherson (1969). The minimum distance between family dens was 3.1 km (mean = 3.9 km), whereas the minimum distance between any two dens was 1 km (mean = 2.2 km). The spacing of all dens in the area also does not depart significantly from random ($p = .74$, $R = 1.05$).

Macpherson (1969) noted territorial behavior may be indicated when R is greater than one, but concluded den density was not limited by territoriality since the observed mean nearest neighbor distance was less than the theoretical maximum. At Prudhoe Bay, the observed mean nearest neighbor family den distance (3.9 km) was less than the theoretical maximum (6.8 km). Adults from neighboring families were not observed within a 3 km radius of the natal den at CC2, and adult foxes were observed chasing other adults in other parts of the oil field. The proximity of many family dens to oil camps was apparent (Figure 3). Though less than maximal spacing between family dens was observed, territorial behavior by adults and apparently exclusive use of areas by

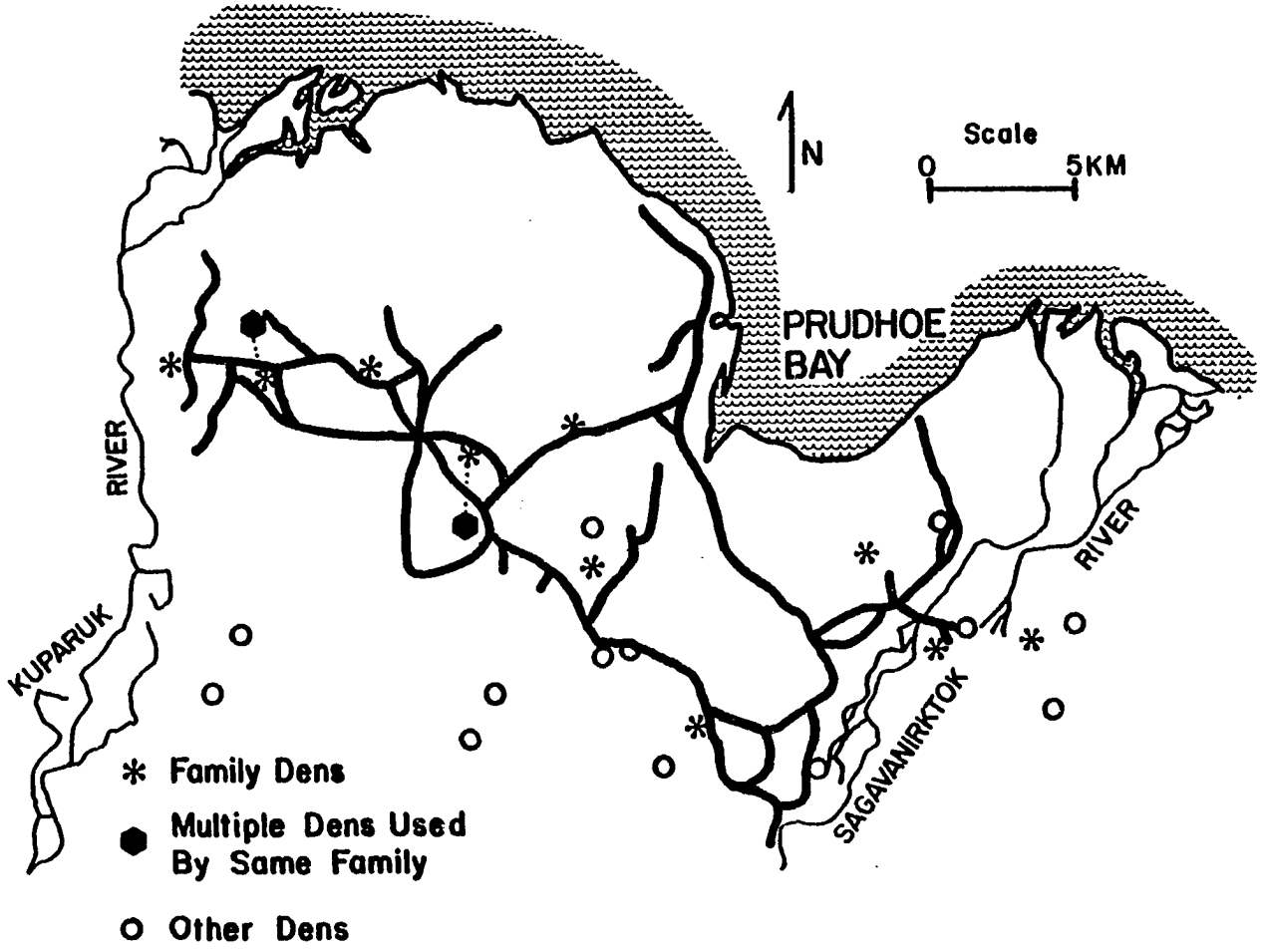

Figure 3. Locations of arctic fox dens at Prudhoe Bay in relation to gravel roads.

family groups did limit the density of family dens during the present study. Hanson and Eberhardt (1977) also showed some indications of territoriality among denning foxes at Prudhoe Bay.

Based on den surveys and repeated travels throughout the study area, I estimated there were 35 adults present at Prudhoe Bay during summer 1979. This included 14 pairs of adults, 11 of which raised pups and 3 whose dens were active only as resting and feeding sites; and other adults from outside the study area who foraged regularly along the Kuparuk and Sagavanirktok Rivers.

Each of the 11 families was checked periodically throughout the summer to assess pup numbers and mortality. Generally, the entire litter was visible only during nursing bouts. The litter also could be censused during adult visits to natal dens since all young pups present greeted returning adults. But such greetings were always chaotic and brief, some pups bolting away with new food and others running out of view. Censusing of older pups (8 to 12 weeks) during adult visits was less reliable since pups did not always greet adults at this age. Also, pups spent more time away from natal dens as they matured and an entire litter of older pups was rarely present in one spot at one time.

During pup counts most dens were observed for 30 minutes or more and the largest number of pups visible at any one time recorded. Barking of pups within dens during surveys also was noted, as were reports of pup movements by oil field employees.

At least 53 pups were whelped in the Prudhoe Bay area and of these 26 (49 percent) were known to be alive at the end of August, although

there may have been as many as 35 (66 percent) alive. Eighteen pups (34 percent) were known to have died. Most simply disappeared although three were found dead, without external wounds, at dens. A rabies test on one of these proved negative, another was badly decomposed and not collected, and the third was gone (and the den abandoned) when I returned to collect the carcass nine days after finding it. Distemper has been diagnosed and rabies suspected among arctic foxes at Prudhoe Bay (Hanson and Eberhardt 1977).

At least one pup died in each of the 11 litters and, as noted earlier, a complete litter of six pups was bitten to death. The field crew finding the six bitten pups claimed the adults were responsible. Unfortunately, the carcasses were disposed of before I could examine them. Adults have been observed to kill and feed on pups (Chesemore 1975). Macpherson (1969) also found six pups bitten to death at a den but suspected quarreling for food was the cause, especially after one of the remaining pups in a captive situation "had caught [a sibling] by the upper jaw and shaken it to death."

Complete histories were known for four litters totaling 28 pups. Sixteen (57 percent) of these 28 pups died, most from unknown causes. This mortality rate agrees closely with Macpherson's (1969) conclusion that 61 percent of all arctic fox pups die before age six months.

A relative index of lemming numbers was made at Prudhoe Bay using snap traps (Pitelka 1973) set at places and times consistent with previous trapping research in the area. Only three small mammals were caught in 2754 trap nights: one juvenile and two adult collared

lemmings (*Dicrostonyx torquatus*). The lemming population was low but appeared to be building from the previous year when no animals were caught (Table 1).

Table 1. Small mammals trapped at Prudhoe Bay from 1975 to 1979

Year[1]	Number caught per 1000 trap nights
1975	9.1
1976	8.7
1977	1.8
1978	0
1979	1.1

[1]Data for 1975 through 1978 from Hanson and Eberhardt (1979).

It is significant that 11 families of arctic foxes were raised in 1979 while lemming abundance was low. In addition, Hanson and Eberhardt (1979) found at least five families of arctic foxes at Prudhoe Bay in 1978, even though the lemming population had crashed (Table 1). Contrary to this, Burgess (1979) noted that no arctic fox pups were produced in the Demarcation Bay area, an undeveloped area approximately 300 km east of Prudhoe Bay, during 1979 when lemming numbers were also low.

Arctic foxes at Prudhoe Bay utilized artificial foods, including camp garbage and handouts. This probably enabled more foxes to reproduce when lemming numbers were low. A. Gavin (pers. comm.) provided data on snowy owl (*Nyctea scandiaca*) numbers at Prudhoe Bay and noted both owl and arctic fox levels are high during years of lemming

abundance. However, snowy owls did not utilize artificial foods at Prudhoe Bay and their numbers were low in 1979 (1 owl seen as compared to 80 in 1976), whereas fox numbers were moderate-to-high.

The population of arctic foxes at Prudhoe Bay is higher during winter than in the breeding season. Oil field workers told me repeatedly of seeing 10 or more foxes congregated around several garbage dumps at Prudhoe Bay in winter. Reports were commonplace of individual employees illegally trapping up to 30 foxes at Prudhoe Bay during winter. Observations by a resident trapper on the Colville River delta (*in* Hanson and Eberhardt 1976) suggest that arctic foxes move from that area to Prudhoe Bay during winter to scavenge for food. Sixteen arctic foxes were marked on the Colville River delta prior to 1978 in an attempt to verify this seasonal movement, and at least one fox moved to Prudhoe Bay between July 1976 and January 1977, while another moved further east into Canada between July 1976 and March 1977 (Eberhardt and Hanson 1978). Underwood (*in* Wrigley and Hatch 1976) also documented the movement of an arctic fox from Banks Island, Canada, west to Prudhoe Bay between August and November 1974.

A regular winter movement of arctic foxes in northern Alaska toward the coast has been described by Chesemore (1968a), and similar movements prompted by local food scarcities were noted in Greenland (Braestrup 1941). It seems likely that high numbers of arctic foxes may congregate at Prudhoe Bay during winter due to local food availability. Perhaps in an analogous situation Chesemore (1968b) observed approximately 40 arctic foxes feeding from a single walrus (*Odobenus rosmarus*) carcass in winter.

No precise estimate of the winter fox population at Prudhoe Bay is available. Approximately 50 private companies as well as numerous field camps and oil facilities occur in the area, and most do not regulate or strictly enforce garbage disposal. This, coupled with feeding of foxes by employees makes large amounts of artificial foods available to arctic foxes. Based on conversations with employees, I estimated 200 or more arctic foxes are present at Prudhoe Bay during an average winter. This compares with 35 adults present and 26 to 35 pups raised during summer 1979.

2. Morphological Development of Pups

Arctic foxes are normally born in underground breeding dens, although in rare instances pups may be born on the ground among driftwood, in rock crevices (Tchirkova 1951), or "under the open sky" (Barabash-Nikiforov 1938). The natal coat is grey-to-black with specks of white on the belly and breast. Both adults are particularly furtive at parturition and the immediate post-natal development of arctic fox pups is poorly understood. I found only one account in the literature of the early development of pups (Novikov 1962):

> Puppies are born blind, toothless and with closed eyes; weight 60 to 90 g. They open their eyes on the 14 to 16th day. The male takes an active part in feeding the little foxes, which grow rapidly. The milk diet continues for 1 1/2 to 2 months, but the pups are given supplementary meat food when they are only one month old.

Some insight into the early maturation process may be garnered from Russian trappers who have chronicled the changing pelage of pups in some

detail. Newborn pups, so-called *kopantsy* ("blind puppies") are covered with a short, brown velvety fur, until they are about two weeks old when the fur becomes longer and lighter. These pups ("diggers") remain in the burrow and continue to grow. *Nornik* ("burrow pups") show a dark dorsal stripe which broadens anteriorly and forms a crosslike pattern in the shoulder region. When the pups disperse from the den at about four months the crosslike pattern is very distinct and they are called *krestovatik* ("young cross foxes"). The fur of pups whitens more slowly than the fur of adults. Juvenile foxes undergoing pelt changes are called *sinyaki* ("blue animals"), and fully mature foxes with white winter fur are called *roslye* ("old timers") (*from* Novikov 1962, Stroganov 1969).

Seven pups I live-trapped at Prudhoe Bay in mid-July 1979, weighed an average 1.44 kg (range = 1.0 to 1.95 kg) or about 40 percent the average weight of four adults trapped in June and July 1979 (mean adult weight = 3.56 kg, range = 3.35 to 4.10 kg). Four of the same pups were weighed again in October 1979 by L. Eberhardt (pers. comm.) and showed increases in total body weight of 133 to 235 percent (Table 2).

The pups showed an average increase in body weight of 30 g per day for the first 6 weeks of life, and 2.9 g per day for the following 12 weeks. The only comparable body weight data I could find noted that a female pup weighed 1.7 kg when captured in July 1976, and 3.55 kg when recaptured as an adult 10 months later (L. Eberhardt unpubl. data). In October 1979, the CC2 pups weighed an average 3.70 kg, slightly more than the average weight of 34 adults, 3.47 kg, given earlier. These

Table 2. Body weights of pups from Construction Camp 2 den at Prudhoe Bay

Pup	Body weight (kg) July 1979	Body weight (kg) October 1979	July-October increase (kg)	Average increase (g) per day June[1]-July	Average increase (g) per day July-October
Female B	1.00	3.35	2.35 (235%)	23	2.8
Female L	1.35	3.15	1.80 (133%)	32	2.2
Male D	1.45	4.35	2.90 (200%)	32	3.3
Male J	1.40	3.96	2.56 (183%)	33	3.1
Average	1.30	3.70	2.40 (185%)	30	2.9

[1]Assuming the pups were born on 7 June 1979, each weighing 90 g at birth.

data indicate pups grow relatively little after the fourth or fifth month and are essentially full grown at the time they disperse from the natal den. Arctic foxes are sexually mature at about 10 months of age, and probably relatively few foxes survive beyond 4.5 years in the wild (Macpherson 1969). One arctic fox reportedly lived 20 years in the Moscow Zoological Garden (Lavrov *in* McEwen 1951).

3. Social Behavior

Remarkably little has been written on the behavior of arctic foxes in the wild. Caley (1972) described some predatory behaviors of captive arctic foxes and Fox (1969a,b, 1970, 1971) reported on some general behaviors of arctic foxes and how these relate to other canids. However, the behaviors of arctic foxes have not been systematically identified and described.

Behavior data were collected in this study to more completely describe the maturation process of young arctic foxes. Learning of new behaviors by pups and the progression by family members from social to solitary during the short summer season were of particular interest. Foxes were observed for about 400 hours and behaviors recorded according to the following categories.

Annotated Behavioral Repertoire

This outline is the first ethogram, or behavioral repertoire, compiled to describe the behaviors of arctic foxes in the wild. The arctic fox is not a social contact species. For most of the year individuals hunt and live alone, close individual contact being the exception rather than the rule. However, in the breeding season, interactions between individuals are more important. Adults assess the breeding condition of other adults, mated pairs cooperate in establishing breeding territories, and individuals must recognize which foxes to tolerate and which to repel.

Resting. Arctic foxes were considered resting if their eyes were closed. Two resting postures were common to all arctic foxes: *curled* and *open*. In addition, pups occasionally rested in *body-contact*.

Curl. When resting in the curled position an arctic fox lies on its side, tucking its forelegs along the belly. The head rests on the forelegs and is covered by the tail which is drawn forward. Only the

most thickly furred portions of the body are exposed to the air in this position, providing for significantly warmer than ambient air temperatures within the curl (Follmann 1978).

Arctic foxes generally rested in the curled position during inclement weather, including cold, rain, and high-wind conditions. They also rested on the leeward side of topographic features to ameliorate the effects of strong winds.

Open. When resting in the open position an arctic fox lies on its belly. The head rests on the forelegs which are positioned forward. The tail lies curled slightly towards the head. Foxes generally rested in the open posture in warm weather, presumably to dissipate heat rather than to conserve it.

Body-contact. Pups occasionally rested together in body contact. There was no particular pattern to this posture, one pup simply sprawled onto another. No more than two pups rested outside the den together in body contact at any one time.

Arctic foxes rested from a few minutes to several hours at a time. They rested at any time of the day, and individual foxes frequently rested in the same spot. Judging from the reactions of resting foxes to activities around them, arctic foxes seemed to be extremely light sleepers. One resting pup suddenly bolted headlong into the den in response to a raven (*Corvus corax*) which called far overhead, for example. Resting foxes aroused themselves frequently and looked around briefly, or shifted positions. Yawning and stretching behaviors were typically seen immediately after rest.

Alert. Arctic foxes were considered alert if they were stationary and awake. Alert foxes in a reclining posture were distinguished from resting foxes on the basis of open *vs.* closed eyes. Alert foxes generally reclined on their side with head upraised, though they occasionally sat or stood motionless in a spot.

Alert was typically a transient state, foxes reacted quickly to whatever information they gathered while alert. For example, a pup may suddenly be distracted by siblings playing nearby, and stop and watch them briefly before approaching or moving away, vocalizing, or responding in other ways. In the absence of stimuli, reclining foxes often closed their eyes and rested.

Grooming. The most frequent grooming activities of arctic foxes were scratching and licking. Fox (1970) noted that among gray foxes (*Urocyon cinereoargenteus*), red foxes, and arctic foxes, only gray foxes show mutual grooming, although E. Follmann (pers. comm.) observed social grooming in captive arctic foxes.

Adults often groomed after returning to the den, particularly in warm weather or in light-to-steady rain. The adult typically moved a short distance from the den and snapped at the pups before lying down to groom. It is interesting that arctic foxes extended their forepaws vertically while licking them, a behavior seen in cats rather than dogs, who extend their forepaws horizontally while licking them.

Radio-collared pups spent more time scratching, usually at their necks, than non-collared pups. While scratching, a fox sat on its

haunches and scratched with hindlimb crossed over forelimb. This posture is common to most birds, reptiles, and mammals, as noted by Lorenz (1958). Sometimes a pup scratched absentmindedly at the air while watching siblings playing. Scratching was always a brief activity, whereas fur-licking sometimes continued for 10 minutes or more. A fox may also briefly lick its nose and lips immediately after agonistic encounters (Fox 1970) and after feeding. Genital licking also occurred.

Scent marking. Kleiman (1966) noted scent marking includes urination, defecation, or body rubbing which is elicited by and directed at familiar or novel objects, and may be repeated frequently on the same spot. Arctic foxes have two types of scent glands; anal glands and a tail gland. Fox (1971) noted that arctic foxes have the strongest tail gland odor among all canids. This is especially effective in maximizing social distance between individuals in a solitary species. Urine and feces may also serve as signals to other foxes (Kleiman 1966).

Scent marking was a particularly intense activity among arctic foxes in late spring. I observed one adult to urinate 19 times in just 18 minutes in early June. I further observed adults to roll frequently in high snow banks, often urinating afterwards. Whether or not rolling served to cover the area with scent or possibly mask the secretions of other foxes, or simply aided in the removal of molting fur or in cleaning the fur, was not known. Arctic foxes also rolled in their own urine, dead prey items, and other redolent substances as has been widely described in many carnivore species.

Arctic foxes commonly defecated on high local relief, a typical canid pattern. They also defecated frequently along waterways or on the surface of frozen lakes. Foxes also defecated repeatedly on the same spot, creating scent stations. A large pile of feces, for instance, was found on a cracked sardine can. Teeth marks indicated passing foxes defecated on the can upon failing to extricate the sardines.

Movement. Movements of arctic foxes may be divided into three broad categories based upon context, body posture, and symmetry and pace of the movement (Table 3).

Table 3. Movement patterns of arctic foxes

Movement	Relative pace	Head position	Direction	Purpose
Travel	rapid	upraised	straight-line	travel towards destination
Forage	moderate	lowered	zig-zag	prey search
Meander	slow	lowered slightly	random	opportunistic

Travel. Arctic foxes generally traveled in a steady trot, but also ran for distances up to 2 km (seen when pups were following adults away from natal dens). Traveling foxes seemed to move with purpose towards a definite goal, whether an area, object, or other fox. An

adult carrying food back to its den, quickly and directly, typified this movement pattern. Arctic foxes moved quickly away from danger or other disturbances (flight response) in the characteristic straight-line travel pattern.

Arctic foxes often traveled along elevated relief, including snowbanks, ridges, and river terraces. They also traveled extensively along the raised gravel roads at Prudhoe Bay. Arctic foxes paused infrequently while traveling. Traveling foxes were simply moving from one area to another and were not hunting, although birds may have been flushed accidentally or nests found.

Forage. Arctic foxes always foraged with their heads lowered close to the ground, and in summer found most of their prey while foraging. Certain areas, particularly river banks, were foraged extensively with the obvious intent of finding prey. To that end foraging was a purposeful behavior. However, other areas, particularly den site surroundings, were foraged by pups seemingly in exploration or play. In such cases, the purposefulness was less clear although the structure of the movement remained the same.

The rate of zig-zag direction changes was rapid in some cases and foraging appeared especially erratic as foxes responded to one or many scents, sounds, or other stimuli in a small area. At other times foxes moved in broad sweeps over large areas, changing directions infrequently and the movement appeared less erratic.

Arctic foxes paused frequently while foraging to investigate spots on the ground, though not as frequently as red foxes who may regularly investigate 220 spots per hour (David 1977).

Meander. Meandering was opportunistic rather than purposeful and commonly used by pups moving around dens. Food caches were found occasionally by meandering pups, though meandering typically ended in play with found objects or other pups. R. Burgess (pers. comm.) did not observe meandering in adults and suggested this behavior is only used by pups at dens.

Prey-catching. Occasionally arctic foxes chased ground squirrels and waterfowl directly, making no attempt at ambush or surprise. At other times they circled geese at a distance, seemingly uninterested, then bolted suddenly at the birds from behind. Small birds were often stalked intently and then pounced at from a lowered crouch. Small mammals including lemmings and voles were either chased in a quick zig-zag course, or dug out from burrows. In the latter instance, foraging foxes leaped suddenly straight-up in the air and came down digging with both forepaws. Sometimes the head remained fixed at ground-level while the rest of the body leaped out sideways. The leap was often repeated once or rarely twice, after which the fox stabbed at the prey item with its forepaw or attempted to dig it out. During biting attacks arctic foxes show the facial expression common to all canids: partially flattened ears and partially or completely closed eyes (Fox 1969b). The

kill bite was normally oriented towards the base of the skull, judging from the condition of numerous skulls and uneaten shrews which we found at dens. Caley (1972) also reported that arctic foxes direct the kill bite towards the base of the skull, and further noted violent head shaking movements accompany the grasping of prey.

Arctic foxes may catch prey at any hour of the day. However, they appeared to be most successful at dawn and dusk when prey species were most active. Burgess (1979) further noted adult foxes are most active between 2000 and 0400 hours.

Feeding. This included all feeding activities exclusive of nursing. The creating and uncovering of food caches was considered feeding behavior.

Small prey items, including birds and lemmings, may be totally consumed in one sitting. Caley (1972) reported mice (*Mus musculus*) were totally consumed by captive arctic foxes and that feeding typically began at the pelvic or facial regions.

Larger prey items were cached after being partially consumed. One CC2 pup fed on a freshly killed ground squirrel (*Spermophilus undulatus*) for 20 minutes, then cached the remainder in four spots over a large area approximately 200 m from the den. Considerable quantities of food may be cached in the den itself. MacFarlane (1908) found 50 lemmings and other prey items in one den, and Macpherson (1969) found 41 lemming carcasses "some ... far from fresh" in the major galleries of an arctic fox den. The CC2 adults occasionally took food into the den, and on

two occasions the adult male brought food out of the den and consumed it himself.

Pups generally took small food items from provisioning adults and bolted in opposite directions to feed alone. Siblings attempted to take food from one another and dominant pups often succeeded after extended chasing or fights. In one instance a pup grabbed a feeding sibling by the hind leg and pulled her in circles amidst loud yelping, but was unsuccessful in usurping the food. One pup may dominate other pups at a larger carcass, repeatedly driving the others away with vehement biting attacks. Adults may also defend large carcasses from other adults (R. Burgess pers. comm.). One pup defended a ptarmigan carcass from five siblings for over an hour, until all moved into the den during heavy rain. Adults, when present, did not interfere in these disputes.

Vocalizations. Arctic foxes possess a fairly large repertoire of barks, squeals, and other calls.

Barking. A short sequence of several quick barks was made in at least two contexts. First, barking served as an alarm call. Pups always responded sharply to an adult's bark, usually bolting directly towards the den. On one occasion a pup ran to greet an adult but pirouetted in mid-stride and raced back to the den when the adult barked at my truck.

In a second context barking served as an information or announcement call. Pups frequently barked at passing caribou, and an adult once barked at me as I approached it on foot. Other foxes generally responded to this call by facing the danger, and perhaps barking themselves. The announcement bark sounded less sharp than the alarm bark, indicative perhaps of a less imminent threat.

Squealing. Pups squealed wildly when greeting adults — a nasal *naaah-naaah* — repeated in series of four to six calls per sequence. Any pup within earshot was attracted to the noise and began squealing as well. Pups also squealed when being supplanted by more dominant siblings, during play, for example.

Yelping. Pups occasionally emitted a single shrill yelp, apparently in pain. This call was usually heard during bouts of rough play and surprisingly did not always stop the activity. During more serious fighting the lesser opponent squealed rather than yelped, and fled at first opportunity.

Rumbling. Arctic foxes gave a throaty rumble when threatening other foxes, a noise Fox (1970) termed "guttural nasal growl." Adults frequently rumbled at pups, and pups rumbled at siblings during disputes over food or play items. Pups responded to rumbling by lying immediately. Sometimes they inched forward while the rumbling continued, but usually became distracted by other ongoing activities and left the area. More lengthy growling noises were given by pups during

protracted fights, and the same lengthy growl was given by trapped adults when approached on foot.

Staccato barking. MacFarlane (1908) noted that arctic foxes sometimes emit "a strange cry much like that of a hawk, a gull, or a brant goose." This was undoubtedly in reference to the staccato bark — a series of *awrr-awrr-awrr* noises — which increase in resonance throughout sequences of varying length. Pups often made this call immediately before entering a den, or immediately after emerging from a den. Perhaps in reference to this call, Fox (1970) noted that captive arctic fox pups emit a "low intensity musical *Cooo-co-co-co-co-coo* when initially introduced [into an area with other pups] after a period of deprivation." The context of staccato barking is seemingly to announce one's presence to other foxes.

Once, a pup barked staccato upon emerging from the natal den at CC2 and a sibling replied in kind from within. After the second pup emerged, both sat 1 m apart and barked staccato directly at one another before turning and barking in the same manner toward a camp building. Two more pups joined in the chorus and the activity continued for 30 minutes. This marked the only mutual vocalization among foxes I observed to continue for any appreciable length of time.

Wailing. This call — a long and mournful *ooooo* — was made in no clear context that I can determine. It was unlike other vocalizations in that no fox was ever observed to react to the noise. Whether it serves as a spacing mechanism during winter is not known. R. Burgess

(pers. comm.) suggested wailing may indicate to an adult fox that its mate is nearby, and noted greeting or play often followed. Bailey and Hendee (1926) noted in apparent reference to this call that it is the "most lonesome sound imaginable."

Greeting. Greeting postures play a central role in the successful mating of adults and in the proper rearing of young. In greeting, the female typically approached the male in a lowered posture with head extended, gaze averted, and ears lowered to the side. Sometimes the female rolled onto her back and vigorously wagged her tail. The male responded by wagging his tail and lowering his head, or standing stiffly and then moving off. The male may also initiate play (R. Burgess pers. comm.). Fox (1970) termed the lowered posture "submissive crouch" and noted that direct gaze and erect ears signal the antithetic threat posture.

Pups typically greeted adults in the lowered posture. They rushed towards the adult with ears lowered, tail wagging, inching forward on their bellies, and squealing. Adults frequently responded with a threatening mouth gape, sometimes combining this with a sharp lunge and bite. If so greeted the pups withdrew about 1 m, but oftentimes quickly approached the adult again, who usually snapped and withdrew. Pups also greeted adults by jumping and biting at the mouth. This caused the adult to regurgitate or drop food which was snapped up by the young.

Pups typically greeted one another with a play intention posture: lowered forequarters and head, raised hindquarters, stiff tail and

direct gaze. Some siblings dominate others and were greeted in the lowered posture. A female pup once approached a male sibling in the lowered posture and investigated his ano-genital region. He stood stiffly then investigated her ano-genital region in return. This greeting was not observed among adults, possibly because I arrived too late in the spring. Fox (1971) showed captive arctic foxes investigating the genital and facial areas of red foxes.

Play. Though the function of play remains obscure, a playing animal is easily recognized by its repetitive and exaggerated movements, and the incomplete and fragmented nature of the activity (Loizos 1967).

Wilson (1975) noted that play includes those activities which "imitate the serious activities of life without consummating serious goals." A popular idea, first propounded by Groos (1898) holds that play provides practice for the young in acquiring and refining behaviors necessary for adult life. However, this does not account for play among adults, and animals need not play to acquire these behaviors (Loizos 1967). Play may partially serve to expend excess energy, strengthen muscles, and stimulate growth (Schaller 1972).

Solitary play. Pups often chewed on objects scattered about the den, occasionally coupling this with head shaking movements and quick body jerks in the manner of killing and eating prey. Pups also cached stones and other non-food items. Single pups carried non-food items

in their mouths and chased objects which blew into view. Solitary play often attracted other pups who usually attempted to initiate social play.

I observed solitary play by an adult only once. A female arctic fox raced around a bull caribou, circling the animal repeatedly at a distance of 2 m or less. The caribou remained in the center of the circle, but turned always facing the fox until she stopped suddenly, remained standing momentarily and then trotted away.

Social play. Several postures were used by foxes to invite social play, including lowered forequarters and exaggeratedly direct stare, pawing, chasing, and pouncing on one another from a lowered crouch. Arctic foxes have a play face whereby the mouth is opened 2-5° and the lips pulled back horizontally (Fox 1970). The play face may be accompanied by head-shaking intention movements. Play postures were often identical to fighting postures, but play was generally noiseless and was distinguished from fighting on that basis. Biting attacks are similar in play and fights, although tail-biting occurs only in play (Fox 1969a).

Pups were far more playful than adults. Pups frequently pounced on siblings, then wrestled or chased each other around the den. An entire litter often played together, then broke-off and continued to play in smaller groups. Pups frequently employed hunting postures in play, particularly stalking and pouncing. Caley (1972) did not observe pouncing in the play of captive arctic fox pups and concluded "it is

not a significant part of the ... repertoire." Contrary to this I found pouncing to be commonplace in the play of arctic foxes in the wild. Pups commonly invited play by stalking and pouncing on siblings and adults.

Two pups often stood and wrestled, forepaws resting on each other's shoulders, biting and jawing until one was knocked off-balance and the two rolled about kicking and biting. Other pups were especially attracted by this activity and usually joined-in. Pups were also attracted by siblings carrying items in their mouths and often played tug-of-war after extended chasing. Such items included ropes, gloves, and visqueen at CC2, and large feathers, bones, and tufts of grass at other dens. The CC2 pups also found the radio collars convenient to grab hold-of during wrestling bouts. Surprisingly they rarely tugged at or bit the protruding whip antennas.

Returning adults always stimulated periods of intense play among pups. Adults occasionally played with pups, usually rolling and wrestling with the young or chasing them and being chased around the den. These sessions were typically brief. Pups occasionally mounted siblings, and on two occasions a pup mounted an adult during play. Pups combined social and solitary play in sessions ranging from less than a minute to an hour or more, and played anytime during the day although mornings and evenings were the most common times for this activity.

Agonism. Agonism is defined here as any activity that serves to increase social distance between conspecifics. This includes threat, attack, and fighting behavior, as well as appeasement and defense.

Arctic foxes vocalized extensively during agonistic encounters. A threatening fox holds its head high, neck arched, ears forward and erect, contracts its lips slightly and stares directly at its opponent (Fox 1970). Piloerection does not occur, arctic foxes being the only canid where this is the case (Fox 1970). Arctic foxes do not bare their teeth but rather *mouth-gape*, opening their mouths as wide as 45°. The ears are flattened during attack and bites are directed at the shoulder, cheek area, and occasionally the muzzle (Fox 1969b). Adults also bit pups around the limbs and neck.

Biting is uninhibited and frequently combined with head-shaking movements that draw blood. Macpherson (1969) observed 20 percent of 330 arctic fox specimens he examined bore marks of puncture wounds on the face. The CC2 pups had ear tags pulled out in several instances during fights.

During high-intensity threats the aggressor often raised its hindquarters and slammed its rump against the opponent. The tail was initially arched over the back and swished vertically as the threat intent increased. Pups also used the raised rump posture in a defensive context, as observed by Caley (1972).

Agonism between siblings was nearly always food-related, one pup attempting to take food from another. Aggression between adults and pups was nearly always directed by adults towards pups, and occurred in a general rather than specific context. Overt aggression between adults may be food-related, as already mentioned, or related to reproduction. Freuchen (1935) noted intruding foxes were chased by a

territorial pair. Stephenson (1970) similarly observed denning foxes to chase intruders, as far as 200 m during 10 minutes. Bédard (*in* Stephenson 1970) also observed "territorial clashes" among denning arctic foxes. Savage fights between males competing for a mate have been reported (Lavrov 1932, Barabash-Nikiforov 1938).

Behavioral Maturation of Pups

Arctic fox pups first appear outside the natal den at age three to four weeks (Eberhardt 1977). Macpherson (1969) noted young pups move relatively little and usually sit "blinking in the sun." At Prudhoe Bay five-weeks old pups moved around the den surface with more alacrity, but did not respond to my vehicle, passing caribou, calling gulls, or other stimuli beyond 40 m from the den. They first reacted to returning adults by running towards them at about the same distance.

At eight weeks pups still spent much of the day inside the natal den (Table 4). Adults occasionally followed pups inside the den at this age, but remained inside only briefly, usually one minute or less. The CC2 adults did not enter the natal den after the pups were approximately 10 weeks old, and by 11 weeks the pups spent only three percent of the day inside the natal den (Table 4). At this age the pups usually entered the den only when alarmed.

The CC2 pups spent increasingly more of the day resting when outside the natal den as they matured (Table 4). Presumably this indicates the pups were resting outside the den where they had previously rested inside, rather than indicating a greater percentage of total day

Table 4. Activity budget for pups from Construction Camp 2 den at Prudhoe Bay

All hours of the day were sampled, although approximately three-fourths of the 300 total hours of behavior monitoring were made between 0800 and 2000 hours.

	Age (weeks)					
	8	9	10	11	12	Total[1]
Percent of day spent inside natal den:	45%	40%	33%	16%	3%	NA
Percent of day spent outside natal den[2]:						
resting	19	16	31	55	-	29%
playing	28	36	25	16	-	27
alert	19	14	10	9	-	13
meandering	13	12	13	7	-	12
traveling	9	10	9	8	-	9
social[3]	4	5	3	1	-	3
grooming	4	2	3	1	-	3
feeding	2	3	3	2	-	2
foraging	1	2	2	0.5	-	2
scent marking	0.4	0.2	1	0.5	-	0.5

[1]age 8 to 12 weeks combined.
[2]insufficient activity data collected for week 12.
[3]includes vocalization, agonism, and greeting.

spent resting. This idea is supported by Caley (1972) who noted captive arctic fox pups spent less time sleeping inside a surrogate den and more time sleeping outside the den as they matured. Caley (1972) further observed that pups sleep in physical contact at age four weeks and gradually decrease physical contact thereafter. I had no data on the resting

behavior of pups inside the den but observed them resting occasionally in body contact when outside the den through age 12 weeks.

Rest was the most common behavior observed among pups (Table 4). From age 8 to 11 weeks the CC2 pups spent approximately 75 percent of each day resting, playing, and inside the natal den. Pups played less as they matured, an observation only partially supported in Table 4. The type, as well as overall frequency of play changed as the pups matured. Pups often incorporated new patterns into solitary play after being led away from the natal den by adults. An eight-weeks old pup was observed caching for the first time, six non-food items in 50 minutes, immediately after returning from an early trip away from the natal den. Solitary pouncing also appeared suddenly in the play repertoire of the CC2 pups at age eight weeks, and approximately three weeks later pups combined zig-zag stalking movements with the pounce. The CC2 pups played at increasing distances from the natal den as they matured. At first they played and moved only in the extreme southwest corner of the camp pad (Figure 2). By 9 weeks they played more at the extremities of the pad, 200 m or more from the den, and at 11 weeks they played anywhere within a 500 m radius from the den.

The pups refined many skills as they matured; stalking and pouncing are cases in point. A five-weeks old pup was attracted away from the den by a snow bunting (*Plectrophenax nivalis*) and approached the bird as though in a stalk, but hesitated as though unsure how to proceed, then ran away. An eight-weeks old pup stalked a lapland longspur (*Calcarius lapponicus*) fledgling alertly from behind, but pounced

ineffectively at the bird from 3 m away. Presumably pups learn in play how best to stalk and pounce on siblings and later apply this knowledge in capturing prey. Schaller (1972) observed improved pouncing in the play of lion (*Panthera leo*) cubs, and Fox (1969b) noted the target area of biting attacks in playing arctic fox pups shifts from the limbs and tail to the facial and head regions (similar to where kill bites are directed) as pups mature.

Although Caley (1972) found "no evidence at any time of a dominance hierarchy or social hierarchy of any kind" in captive arctic fox pups, I noted at several dens that some pups consistently dominated siblings. I further observed that the hierarchies became more distinct as pups matured, being firmly ensconced by age 10 weeks. The flight distances of five pups, aged 10 weeks, observed one morning at CC2 reflected the hierarchy I had assumed to exist. A bull caribou wandered within 50 m of the pups playing about 200 m from the den and the pups immediately became alert. At 30 m pups K and L ran back to the den, the rest laid low in the grass. At 15 m, J and B ran towards the den but stopped half-way and sat. Pup D remained alone and raced around the caribou, who turned and faced D and then moved away. In this instance, flight distance was inversely correlated with dominance. Pup D regularly took food from the others, especially K and L, who never attempted to take food themselves. This reflected dominant and subordinate status, respectively. Pups J and B were of fairly equal middle-status, occasionally taking food from subordinates, but never from D. It is interesting to note that pups of equal status, especially J and B,

and D and N (another dominant pup), frequently traveled together, often leaving the natal den together and returning at the same time.

Arctic fox pups showed rapid behavioral maturation, closely paralleling rapid physical growth. Besides spending less time inside the natal den and incorporating new patterns into play and social relationships, the activities of pups in general became distinctly more purposeful and precise as they matured. At age eight weeks the CC2 pups spent 19 percent of the day outside the natal den alert, or without motion, merely watching stimuli without reacting, and 13 percent of the day meandering about, without immediate purpose (Table 4). By age 11 weeks, the time spent on these behaviors was halved (Table 4). I did not observe 12-weeks old pups capturing prey, but presume they did so, especially since the CC2 adults were no longer bringing food to the natal den at this age.

Changing Interactions Between Family Members

During early spring mated adults establish breeding territories from which they exclude other foxes (Freuchen 1935, Stephenson 1970). Prior to estrus the mated pair plays and travels together in close contact throughout the breeding territory. The female enters the den several days before giving birth, and remains inside until several days thereafter. The female has an exceptionally strong den site fidelity at this time, as evidenced by the refusal of a recent mother I had trapped to leave the den, even after she escaped. She merely ran off 10 m and barked at me until I left.

The movements and activities of the adult male at parturition are poorly understood. In early July, when most pups at Prudhoe Bay were five weeks old, adults often arrived at natal dens at approximately the same time and from the same direction, presumably coordinating movements at a distance, rather than moving in close contact as before. Greetings between adults appeared cursory at this time, and less affectionate than earlier in the spring. As the summer progressed adults traveled more independently, and were rarely seen together after mid-July. Both adults came to the den at CC2 at the same time apparently by coincidence on 29 July and did not greet or otherwise interact. The male left immediately after the female arrived.

Increased avoidance between adults was the first stage in the dissolution of the family of arctic foxes at CC2. The second stage was increased avoidance between adults and pups.

Data summarized in Table 5 shows both adults made generally fewer visits per day to the natal den as the pups matured. When the pups were between 5 and 12 weeks old, the male typically spent less than one percent of the day at the natal den. The average percent of day spent at the den by the female dropped sharply from 100 percent at birth to 27 percent at 5 weeks, to between 2 and 7 percent during 8 to 11 weeks, and zero percent at 12 weeks. The amount of food the male brought to the natal den dropped sharply between five and eight weeks; whereas the female brought food as long as she returned to the natal den. At CC2 the male brought no food after returning with a scrap in a plastic bag on 22 July, the pups then being about eight weeks old. The CC2 female

Table 5. Adult visits to natal dens at Prudhoe Bay

Observations of 5-weeks old pups were made at Airport den during 4 days and totalled 23 hours, all during 0800-2000 hours. Observations ended when the litter of 8 pups was moved. Data for weeks 8-12 were collected at Construction Camp 2 (CC2). All hours of the day were sampled at CC2, although approximately three-fourths of 400 hours spent there by us were between 0800 and 2000 hours.

	Age of pups (weeks)					
	5	8	9	10	11	12
Adult male						
no. visits (per day)	3.1	1.6	1.2	1.9	0.3	0.6
percent with food	100	29	0	0	0	0
ave. percent of day present	0.8	0.9	1.8	5.8	0.4	0.6
Adult female						
no. visits (per day)	6.2	2.1	2.1	2.8	0.9	0
percent with food	83	67	71	89	33	0
ave. percent of day present	27.1	3.6	6.9	1.9	6.4	0

continued to bring food through 13 August, but was not seen again after arriving with a lame foot on 17 August. Observations of 57 adult visits to natal dens showed the average duration of each male visit was 20 minutes (range 1-89, s.dev. 23), and each female visit averaged 34 minutes (range 1-213, s.dev. 46). The average duration of visits by adults did not change as the pups matured.

Underwood (1975) noted the reactions of adult arctic foxes to persons at natal dens change from aggressive in June to indifferent in August. In June, the female may bark at people and attempt to distract them from the newborn pups (Eberhardt 1977). Adults were present on

four occasions while we tagged pups at dens in July and reactions were generally intermediate between aggressive and indifferent. All remained nearby during the procedure, indicating den site fidelity was still strong. On 11 July, a male sat 70 m away and watched silently while we collared a pup. On 17 July, the CC2 female vocalized and repeatedly charged towards us, especially responding to the faint yelping of three pups while we tagged their ears. At one point she ran within 2 m of us and bit our supply box and dragged it a short distance away. On 18 July, a female, herself later captured, investigated our equipment and urinated on some of it while we tagged two of her pups. On 19 July, the CC2 female was again present when we tagged two additional pups and her mate, although this time she sat 20 m away and watched, barking occasionally. Neither CC2 adult thereafter approached the den without barking at our vehicle or at least circling it first at a distance. The pups habituated to the vehicle within a few days.

In addition to visiting the natal den less often, bringing less food, and showing tempered reactions towards people at the natal den, adults became increasingly aggressive towards the pups as they matured. Aggression towards young pups was normally limited to mouth-gaping, and occasionally included snapping. Older pups were chased and bit. Most older pups continued to greet adults as long as they returned to the den, regardless of the consequences. Others greeted adults less often, and an 11-weeks old CC2 pup bit back at the adult female and fought with her briefly before other pups arrived and interrupted the activity.

Adult aggression towards pups intensified in late July, about the same time the adults ceased to interact with one another. Adults also showed the first white fur of autumn molt in late July, suggesting a correlation between physiological and behavioral changes.

The final stage in the family break-up was increased avoidance between pups. This was the most gradual and subtle of the three stages and was reflected primarily in expanding home range sizes and increasingly exclusive use of areas (more fully discussed in the next section).

Interactions between pups became limited since individuals concentrated their movements in distinct areas. Caley (1972) noted captive arctic fox pups avoided casual contact at age 70 days and totally avoided one another at 100 days. I observed pups playing through age 12 weeks, though infrequently since several pups were rarely in an area together at this age. The increased avoidance and aggression observed by Caley (1972) may be a function of the small-sized pens in which the pups were kept. Perhaps these pups established individual home ranges on a micro-scale inside the pens and showed aggression less likely to be observed in the wild.

During a two hour period on 14 August all of the CC2 pups, 11 weeks old, were away from the natal den at the same time, marking the first instance since parturition that no foxes were present at the natal den. Thereafter the pups were rarely seen, although each visited the den for brief periods through the end of August. Based on continued telemetry monitoring, L. Eberhardt informed me that four CC2 pups were still in the vicinity of the natal den in October, at 19 weeks of age. One pup,

male N, was not observed directly or by radio telemetry and presumably had left the Prudhoe Bay area. The adult male, last seen on 22 August, was also not observed and presumably had also dispersed. The adult female was not observed after 17 August.

4. Space Utilization

General

Movements of arctic foxes have been classified into four general categories: *local*, the daily travels of an individual; *seasonal*, relatively short distance movements correlated with seasonal changes; *sporadic*, unpredictable long-distance movements by individuals; and *migration*, long-distance directional movements by groups (McEwen 1951). Early movements by pups around natal dens often involved several individuals moving short distances in a sustained direction, and so did not fit conveniently into any of the four given categories. Thus the first movements by pups around the natal den until the time they, or the adults, permanently disperse from the den are defined here as *exploratory*.

Arctic foxes are capable of moving great distances. Movements by individual foxes of 1000 km in 102 days and 1530 km in 250 days have been recorded (*see* Wrigley and Hatch 1976). Single foxes have been observed on sea ice at latitude 88°N, 800 km from the nearest land; and 141 km from the true North Pole (Underwood 1971, Wrigley and Hatch 1976). Long-distance movements reported by Eberhardt and Hanson (1978) for foxes tagged in northern Alaska range up to 945 km, and an

additional movement of 2000 km was reported for a fox trapped and released at Prudhoe Bay (Hanson and Eberhardt 1979). Reasons for sporadic movements are not clear since they are sometimes made irrespective of local food availability (Eberhardt and Hanson 1978).

Migrations of arctic foxes in Alaska have not been described; directional movements appear to be seasonal only (Chesemore 1968a). Beginning in late summer most foxes in northern Alaska move towards the coast and some onto sea ice. In late winter the foxes return inland, where they breed and spend the summer.

Definite migrations of arctic foxes moving south and southwest from Nenetskii, Okrug, and the Yamal Peninsula in northern U.S.S.R. and along south-draining waterways in Manitoba have been recorded (Shilayaeva 1967, Wrigley and Hatch 1976). Seton (1929) noted arctic fox migrations are more properly emigrations; a dispersal of the surplus young of the year. However, research has shown migrating populations are composed primarily of adult males (Pulliainen 1965, Vibe 1967).

Where reported, arctic fox migrations usually occur every three to five years and may be triggered by reduced availability of prey, increased numbers of foxes, or unusually poor weather (Shilyaeva 1967). The migration may consist of several waves, or "yuros" (Dementyeff 1955).

Most migrating foxes seemingly die from starvation, in traps, or from disease (*see* Wrigley and Hatch 1976). Up to 75 percent of a migrating arctic fox population may be affected by rabies (Syizyumova 1967). Data given by Braestrup (1941) on the cyclic invasion and disappearance of white foxes in northwestern Greenland suggests a return

of migrants, and Dementyeff (1955) observed a gradual, post third-wave movement of foxes traveling back to the tundra in early spring to breed.

Initial Movements from the Natal Den

Prior to age five weeks arctic fox pups rarely moved more than 20 to 30 m away from the natal den. Pups occasionally traveled away from the den during play chases, but at age five weeks most movements away from the den were in the presence of adults. Pups ran away from the den to intercept returning adults, followed adults away from and around the den, and ran after adults departing from the den. Pups younger than six weeks were unable to keep pace with adults, and generally returned quickly to the den after running 50 m or less.

Adults led pups on extended trips from the natal den starting at approximately six weeks of age. The complete litter, age six weeks or older, was sometimes moved to a new den particularly if the natal den was disturbed. Three litters out of 11 were moved the day after I visited the dens, and a fourth litter was moved (from Airport den) shortly after I began observations. Underwood (1975) also noted a litter of arctic foxes was moved the day after he first visited their den.

The first extended trips by pups away from the natal den were led by adults, who stopped occasionally for stragglers and traveled at a pace amenable for the pups. Since arctic foxes have no "follow-me" vocalization, adults utilized the strong following instinct of the pups

as well as their own behavior to coordinate early trips. Adults moved back and forth short distances from the den in apparent effort to entice pups into following them. The same behaviors were used by the adult female at Airport den while permanently moving her pups to a new den. Quoting from my field notes:

> 8 July. 16:20. The female moves 60 m west off the den to a pond and sits. One pup hesitates at 40 m, then runs to join her. The rest of the pups sit at the den and watch. After 5 minutes the female and pup return to the den. Ten minutes later the female moves again to the pond and 4 pups follow. After 2 minutes the female runs 100 m further west. One pup follows, 2 go half-way, then stop and watch, 1 pup runs back to the den. The female returns to the pond and all play. After 1 minute the female runs 250 m southwest and 1 pup follows, running hard to keep pace. The female turns twice and waits for the pup before running again. I lose sight of the pair at about 1 km. The other pups return to the den.
>
> 9 July. Only 7 pups present when I arrive at 12:40. At 12:50 the pups run 80 m off the den to greet the adult female returning with food. Twenty minutes later the female moves off the den to the pond and sits, 5 pups follow her there. After 4 minutes all return to the den. Three minutes later the female runs 300 m southwest and 6 pups follow her. The female stops twice and they all gather before starting again. The pups follow the female for at least 2 km, running hard, until out of my view. One pup is still at the den, playing alone. [The last pup was gone by the next morning, presumably moved overnight].

The female quickly enticed the pups into moving increasing distances away from the den. The pattern of adult enticement; moving increasing distances away from the pups and waiting for them, was also used by adults leading pups on temporary trips from the natal den. For example, the adult male at CC2 once moved back and forth short distances from the den and stopped when a pup (male D) followed but could not keep pace. The pup sat 200 m from the den, the adult male returned and played with

him briefly before both moved again. On another occasion the adult male at CC2 waited for three pups who hesitated on the opposite side of a road before crossing, clearly leading the pups rather than merely being followed by them.

It is interesting that the adult male at Airport den did not visit the den during the two days the pups were permanently moved, whereas he visited the den four times in six hours the preceeding day. Whether or not his absence prompted the move or was otherwise related to the sequence of events was not known.

Adults still led most trips by pups through age eight weeks, although at this age some pups traveled away from the natal den alone. By age 10 weeks pups followed adults away from the natal den less often, and some pups traveled away from the den together. After age 10 weeks pups generally traveled alone, though most continued to follow adults around the immediate den area and play with other pups.

Home Range

Home ranges of young pups were restricted to the immediate den area, and gradually expanded as the pups spent more time away from the natal den and traveled independently of the adults. Although individual differences were observed, the CC2 pups spent less time at the natal den as they matured. Average percent of day present at the natal den by all pups dropped sharply after 10 weeks of age (Table 6). Among the pups, dominant males D and N were generally present least at the natal den each week. In contrast, subordinate female L rarely left the den

Table 6. Average percent of day present at natal den for Construction Camp 2 (CC2) pups at Prudhoe Bay

All hours of the day were sampled, although approximately three-fourths of 400 hours spent at CC2 by us were between 0800 and 2000 hours.

	Age of pups (weeks)				
	8	9	10	11	12
Pups					
Male D	46%	50%	40%	15%	2%
Male N	57	39	65	23	30
Male J	93	48	82	53	31
Female B	84	98	80	47	28
Female L	97	97	97	98	69
All pups	75	74	73	47	32

until age 12 weeks, frequently remaining there alone, not following adults like other pups. Once, the adult female returned to the den with a lemming, but ran off still holding the food when greeted by L, seemingly (and successfully) attempting to lure L on a short trip away from the den.

Most of the early movements by the CC2 pups away from the natal den were made between the natal den and a secondary den, located in a pingo approximately 2.5 km from CC2. The litter was not split between the two dens. Rather, the pups moved freely between the dens, led at first along a dry river bed by the adults, then by themselves using alternate routes, later in the summer.

Location data collected by radio telemetry for the CC2 pups are shown in Figure 4. At age 8 to 12 weeks, locations for most pups were

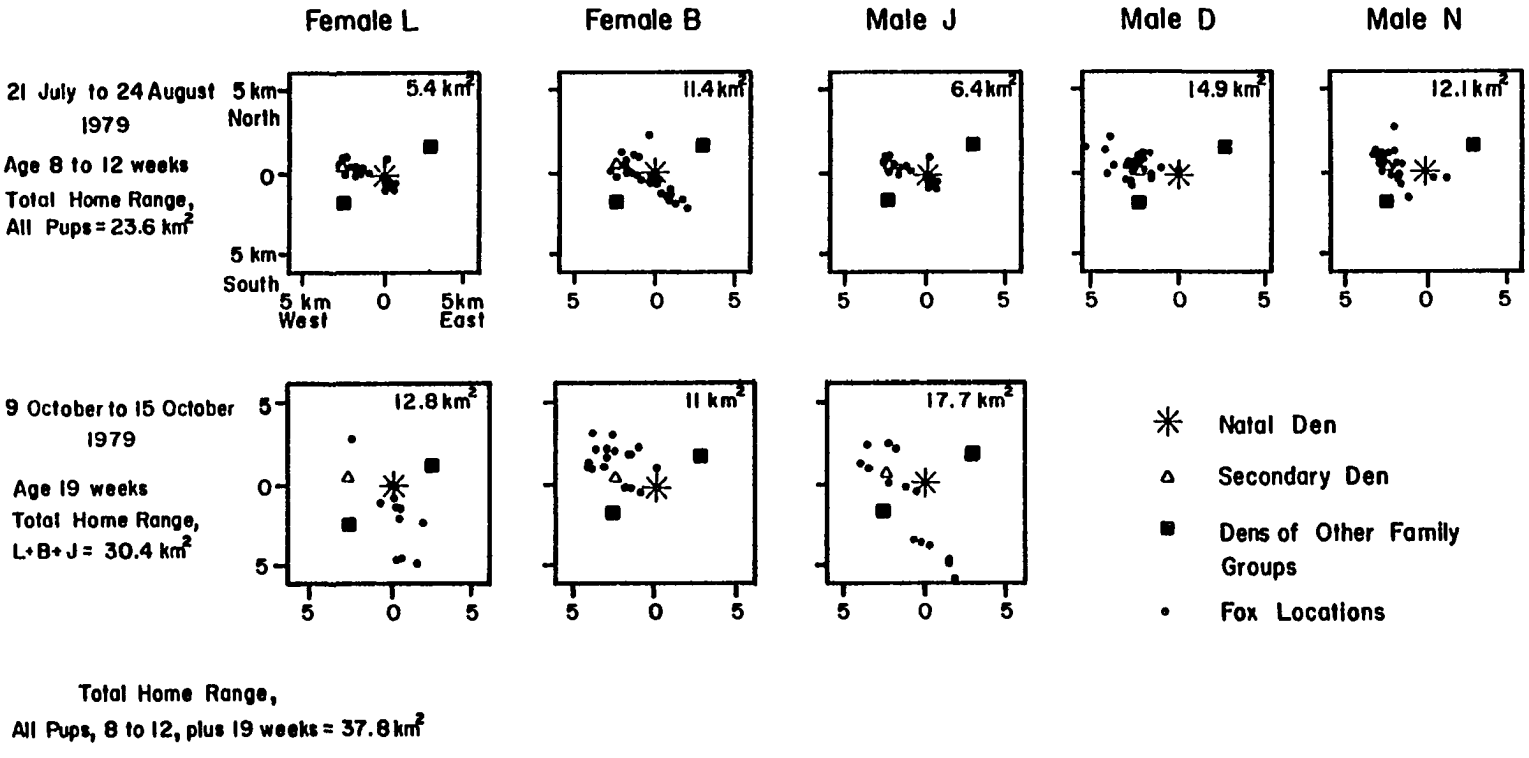

Figure 4. Location data collected by radio telemetry for Construction Camp 2 (CC2) pups at Prudhoe Bay. Numbers within boxes indicate size of individual home ranges. Male N was not observed directly or by radio telemetry in October, and presumably dispersed from Prudhoe Bay between August and October. Only limited data (not shown) were collected for male D in October (October data collected by L. Eberhardt).

clustered around the secondary den, or areas between the natal den and secondary den, presumably reflecting frequent adult-led trips to the secondary den. Only male D moved regularly beyond the secondary den. Female B made several trips southeast of the natal den, possibly because workers fed her from a camp in that direction. Home range sizes varied from 5.4 to 14.9 km^2, and the home range for all pups combined was 23.6 km^2 (Figure 4).

By late summer the CC2 pups generally traveled in discrete areas, seemingly partitioning the larger area used by the adults. For example, female L remained near the natal den, male D remained near the secondary den, and female B stayed near the feeding camp.

By age 19 weeks individual movements were less concentrated around the natal den (Figure 4). Seton (1929) observed "the impulse to go is born apparently in every junior Fox." But only one pup, male N, possibly dispersed away from Prudhoe Bay. Home ranges for pups who stayed varied from 11 to 17.7 km^2 (Figure 4). Pups L and J increased their home ranges 137 and 176 percent, respectively. Female B showed a slight decrease in home range size, but shifted her area of use from southeast to northwest of the natal den (Figure 4). At age 19 weeks the home range for all pups combined was 30.4 km^2, an increase in area of 29 percent from August.

It is noteworthy that male pups generally had larger home ranges than female siblings, and a male may have dispersed away from the natal area. This suggests males may typically move farther than females. Research cited earlier noted that migrating populations are composed

primarily of adult males; and among red foxes Philips *et al.* (1972) found that the tendency for males to disperse from the natal area was greater than for females. Dementyeff (1955) further noted adult female arctic foxes remain comparatively nearer natal dens than males do. We were unable to monitor the movements of the CC2 female directly. But the CC2 male, outfitted with a radio collar, usually moved quickly out of receiving range (about 3 km), suggesting a larger home range than the female who often remained near the den or returned shortly after leaving. Burgess (1979) also noted males moved out of receiving range and females did not.

The total home range used by all CC2 pups was 37.8 km^2 (Figure 4). This was greater than the maximum home range of 26 km^2 reported for denning adult arctic foxes at Prudhoe Bay (Hanson and Eberhardt 1979), and less than the approximately 51 km^2 area used by adult females at Demarcation Bay (Burgess 1979).

5. Food Habits

Numerous food habits studies have been made for arctic foxes throughout their range. Summer food habits are well documented, and though regional differences occur, the summer diet is well summed-up by Seton (1929) who noted "the Fox is ashore feasting on birds and Lemmings." Other small mammals are eaten, as well as insects and such diverse items as fish, marine invertebrates, berries, caribou and marine mammals (Barabash-Nikiforov 1938, Braestrup 1941, Macpherson 1969, Stephenson 1970), frogs and arctic foxes (Shibanoff 1951), and such

anomalies as rope, shoe leather, and bits of rubber (Seton 1929, Chesemore 1968b).

All summer food habits studies indicate small mammals, particularly lemmings, to be the mainstay of the diet of inland arctic foxes. Macpherson (1969) found lemmings occurred in 50 to 90 percent of 4653 scats of denning arctic foxes in Keewatin District, Canada; frequency of occurrence dropping as lemming abundance declined. Shibanoff (1951), working in unspecified areas of the U.S.S.R., noted the basic food of pups consisted "of mouse-like rodents, and especially of lemmings"; small mammals occurring in 72 to 83 percent of 1158 scats.

Fish and birds occur more frequently in the summer diet of arctic foxes living on islands or other maritime areas. Based on stomach and scat analyses, Barabash-Nikiforov (1938) found the "ratio" of birds in the diet of arctic foxes on Copper Island was 40 percent, fish 15 percent, and mammals only 7 percent. Other important foods on Copper Island included marine invertebrates (Barabash-Nikiforov 1938). Stephenson (1970) reported a small mammal occurrence of 91 percent in scats of arctic foxes denning on the lowlands of St. Lawrence Island, whereas small mammal occurrence was only 22 percent and bird occurrence 97 percent in scats of foxes denning near sea cliffs. In different upland areas foxes took birds according to the accessibility of their nests, while similarly on the lowlands foxes preyed on tundra voles (*Microtus oeconomus*) — the most abundant small mammal on the island (Stephenson 1970).

Table 7. Food habits studies of arctic fox populations in northern Alaska

Identified food remains expressed as percent occurrence in total scats.

	Prudhoe Bay this study	North Slope Eberhardt (1977)		Teshekpuk Lake Chesemore (1968b)	
	Summer 1979	Summer 1974	Spring + Summer 1975	Summer 1962	Winter 1963
Number of scats	105	107	583	200	39
Total mammals	87%	67%	68%	99%	97%
Marine mammals	-	-	-	1	8
Caribou	-	-	-	15	5
Total small mammals	87	67	68	95	90
Total lemmings	76	54	64	NA	NA
Collared lemming	22	43	47	3	-
Brown lemming	56	11	16	85	87
Red-backed vole	-	-	-	-	-
Tundra vole	-	4	-	-	-
Ground squirrel	4	9	4	-	-
Unidentified small mammals	7	-	-	12	-
Birds	38	40	48	56	26
Fish	-	-	-	2	-
Insects	30	tr.	2	8	-
Marine invertebrates	-	-	-	1	-
Vegetation	79	14	41	*	*
Garbage	26	-	11	3	18

*Chesemore (1968b) noted vegetation occurred in almost all summer scats and most winter scats.

These studies indicate the summer diet of arctic foxes consists of the most locally available food. This includes small mammals on inland sites, primarily lemmings but voles where these predominate, and birds, fish, and marine invertebrates on islands or other maritime areas.

Results of the scat analysis are shown with similar studies made in Alaska in Table 7. Small mammals were the only mammal remains identified in scats, occurring in 87 percent of 105 scats. Caribou bones were found at other dens, though their degree of utilization as food is not known. One dead caribou washed up on the shore of a small lake during early August and to my knowledge was not utilized by arctic foxes during approximately two weeks. This agrees with the observation by Stephenson (1970) that available carrion was not utilized by foxes in summer on St. Lawrence Island.

Lemmings occurred in 76 percent of all scats, brown lemmings (*Lemmus trimucronatus*) more frequently than collared lemmings, though both species sometimes occurred in the same scat. It is noteworthy that lemming indices for 1975 and 1979 at Prudhoe Bay were 9.1 and 1.1, respectively (Table 1), while corresponding lemming occurrence in scats was 64 and 76 percent, respectively (Table 7). Macpherson (1969) noted lemming occurrence in scats declined as lemming abundance decreased, but that relationship was not evident in this study. However, differences in area and seasons sampled between Eberhardt (1977) and the present study may be sufficient to preclude direct comparisons. Further, I suspected the local lemming population around CC2 and the Kuparuk

River was higher than for the general Prudhoe Bay area, since lemming remains seemed less common at other dens.

Ground squirrel remains occurred in four percent of all scats and were the only other mammal remains identified in scats. However, other observations indicated that four percent occurrence probably understates the importance of ground squirrels in the summer diet. We observed frequent chases of ground squirrels by arctic foxes, noted their remains at most fox dens, and observed ground squirrels brought to the CC2 pups by both adults on several occasions. Macpherson (1969) noted larger prey items leave fewer remains in fox scats per volume of meat than smaller prey, which may partially explain why ground squirrel remains occurred less frequently in scats than is warranted by their seeming importance.

Bird remains occurred in 38 percent of all scats. It is not known to what extent egg shell fragments represented natural prey or handouts from CC2 workers. Small birds, including snow buntings and lapland longspurs, were brought to the CC2 pups by the adult female on at least several occasions. Waterfowl, ptarmigan, and other large bird remains were found at most other dens, but were not observed eaten at CC2.

Insect remains occurred in 30 percent of all scats, and vegetation in 79 percent. No observations were made of arctic foxes purposefully consuming berries or insects as noted elsewhere (Braestrup 1941, Shibanoff 1951, Macpherson 1969). Pups occasionally chewed on grasses around the den area, however. Chesemore (1968b) found vegetation in

"almost all" of 200 summer scats but noted it was probably ingested accidentally with other foods.

Garbage was found in 26 percent of all scats, though I believe artificial foods were utilized extensively. Handouts generally consisted of processed foods (including donuts and sandwiches) which may have been digested more fully and left fewer identifiable remains in scats. These and other foods were available to arctic foxes in large quantities. The adult female at CC2 occasionally entered the den with three or more sandwiches at a time, and I saw one worker give six donuts to a single pup in just 10 minutes. Steak bones were found at all dens, even those 3 km or more from the nearest camp, and the CC2 pups often sat near the kitchen door on steak nights, though workers never gave steaks to foxes in my presence.

Extensive utilization of artifical foods by arctic foxes has been noted elsewhere. Barabash-Nikiforov (1938) found some arctic foxes on Copper Island fed "chiefly on garbage found near human dwellings." Shibanoff (1951) noted arctic foxes in unspecified parts of the U.S.S.R. "showing almost no fear of man, entered villages and foraged in garbage dumps. Residents chased them and killed them with sticks." Urquhart (1973) reported arctic foxes followed seismic camps on Banks Island inland during the fall, and further noted fox numbers in the camps declined after garbage was incinerated.

Based on food remains at dens, scat analysis, and observations of hunting foxes throughout the study area, it was my impression the summer diet of adults consisted equally of small mammals and birds. Artificial

foods seemed utilized more extensively by pups than by adults. Pups too young to hunt efficiently on their own easily found artificial foods while foraging around camps. Adults generally brought natural food to pups, who seemed to prefer natural food over artificial foods.

Winter food habits are not well documented. Arctic foxes may eat resident birds and small mammals where available (Chesemore 1968b), though the winter diet is apparently supplemented to a large extent by carrion. Quoting resident trappers on St. Lawrence Island, Stephenson (1970) noted carrion bait attracts arctic foxes after November, but not before, and confirmed beach carrion was available but not utilized by foxes during summer.

According to oil field workers at Prudhoe Bay, arctic foxes occasionally kill winter resident birds including ravens, but garbage is undoubtedly utilized more extensively in winter than in summer. As noted earlier, foxes may be attracted to Prudhoe Bay from surrounding areas in winter due to availability of artificial foods. Urquhart (1973) noted foxes congregated in seismic camps on Banks Island temporarily during winter, then moved on. Residence patterns of arctic foxes at Prudhoe Bay, and how these patterns may relate to winter food habits, are not known. Several studies have noted arctic foxes may follow polar bears (*Ursus maritimus*) on sea ice during winter and scavenge from bear kills (Braestrup 1941, Tchirkova 1951, Chesemore 1968b, Macpherson 1969, Wrigley and Hatch 1976).

SUMMARY

Arctic foxes were studied at Prudhoe Bay, Alaska, during summer 1979 as part of a continuing effort to assess the impacts of northern oil development. Arctic foxes may provide a relative index to food-based changes in the environment since their productivity generally reflects the vigor of small mammal populations in a local area.

At least 35 adult arctic foxes were present in the Prudhoe Bay area during the summer. Twenty-six arctic fox dens were surveyed and classified according to intensity of fox use. Adult foxes visited 23 (88 percent) of the dens and used them to varying degrees. At least 53 pups were whelped at 11 family dens, and 26 to 35 (49 to 66 percent) pups survived until the end of August. The causes of pup mortality were largely unknown, although one complete litter of six pups was found bitten to death, and a rabies test on another dead pup was negative.

The density of arctic fox dens at Prudhoe Bay (one den per 15 km^2) was among the highest recorded in the literature. Locations of family dens did not depart significantly ($p = .15$) from random, and the mean nearest neighbor family den distance (3.9 km) was less than the theoretical maximum (6.8 km). However, territorial behavior was implicated in limiting den density since mated pairs seemingly moved in exclusive use areas. Close proximity to artificial food supplies may have also been an important factor in den site selection.

Small mammal trapping indicated lemming abundance was low. The arctic fox population was at a moderate-to-high level compared with

previous findings in the area. Foxes feeding at unregulated garbage dumps, and direct observations of food handouts to foxes by oil field employees confirmed artificial foods were being utilized. However, garbage remains were identified in only 26 percent of 105 scats; birds in 38 percent; and small mammals in 87 percent. Handouts typically consisted of processed foods, including donuts and sandwiches, which may have left fewer identifiable remains in scats than natural foods. Pups utilized artificial foods more than adults, and all foxes seemingly preferred natural foods. Artificial foods may be utilized more extensively by foxes in winter than in summer, and artificial food availability may even attract foxes to Prudhoe Bay from surrounding areas. It was estimated 200 or more arctic foxes are present in the Prudhoe Bay area during winter.

Increased food availability during years of low lemming abundance probably enables more foxes to reproduce and is a positive short-term impact of oil development in northern Alaska. A benefit to arctic foxes in over-winter survival may also accrue.

However, increased intraspecific contact among foxes occurs around garbage dumps and may exacerbate transmission of diseases, including rabies. Arctic foxes are especially susceptible to rabies, and because of a long species-specific latency period, may carry the infection over long distances before succumbing. Long-distance movements ranging to 2000 km by individual foxes away from Prudhoe Bay have been documented elsewhere and suggest foxes crowding around garbage dumps may be a significant new vector for rabies in northern Alaska and beyond. The

long-term impact of artificial food availability at Prudhoe Bay is potentially adverse to arctic foxes and northern populations of wildlife and man.

Pups grew rapidly. At age six weeks, seven pups weighed an average 1.44 kg, or about 40 percent the weight of four adults weighed at approximately the same time. Four of the same pups were adult-size, weighing an average 3.7 kg, at five months of age.

By age three months pups from one family group (CC2) started to partition the larger home range of the adults into discrete individual use areas. Home ranges of five CC2 pups, as determined by radio telemetry monitoring, varied from 5.4 to 14.9 km^2 in July and August. In October, three of the same pups used 11 to 17.7 km^2, and one pup possibly dispersed away from Prudhoe Bay. The combined home ranges of all radio-collared CC2 pups covered 37.8 km^2. Male pups generally had larger home ranges than female siblings, and the adult male at CC2 seemingly moved further from the natal den than the adult female.

Both adults assisted in rearing the young; providing food and leading pups on short trips from natal dens. Adults began traveling independently of one another by mid-summer, about the time their first white winter fur appeared. Increased avoidance between adults was the first of three stages in the family break-up. Later in the summer adults visited natal dens less often, brought less food to the pups, and became increasingly aggressive towards the pups. Increased avoidance between adults and pups was the second stage in the family break-up. The third stage, increased avoidance between individual pups, was

primarily reflected by the pups' expanding home ranges and increasingly exclusive use of areas. By age five months social ties between pups were seemingly dissolved, and adults had abandoned the natal dens.

The first ethogram, or behavioral repertoire, for arctic foxes was developed, identifying 11 major behavior categories. Based on 300 hours of behavior monitoring, approximately three-fourths of which occurred between 0800 and 2000 hours, the most common activities for 8 to 12 weeks old pups outside the natal den were resting (29 percent of day) and playing (27 percent). Pups seemingly improved such hunting skills as pouncing and stalking during play, and often incorporated new patterns into play after returning from early adult-led trips away from natal dens. Definite dominance hierarchies were observed among pups at several dens. Dominant pups defended food items from other pups, took food from subordinate pups after extended chases and fights, and spent less time at natal dens and had larger home ranges than subordinate siblings.

Pups spent less time inside natal dens, and less time around natal den areas as they matured. At age 12 weeks the CC2 pups entered the natal den only when alarmed, an average of only three percent of the day. In addition, at the same age, all CC2 pups spent an average of only 32 percent of the day at the natal den; though individual variation ranged from 2 percent of the day present for dominant male D to 69 percent for subordinate female L.

Rapid behavioral maturation of arctic fox pups closely paralleled rapid physical growth, expanding home ranges, and increasingly exclusive

use of areas. The break-up of large and social family groups to solitary foxes progressed rapidly, and was seemingly correlated to the short summer season typical of high arctic environment.

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